

# Hydrogen Delivery: An Option to Ease the Transition



Presentation at:

## The DOE Hydrogen and Fuel Cells Coordination Meeting

Washington, D.C.

June 3, 2003

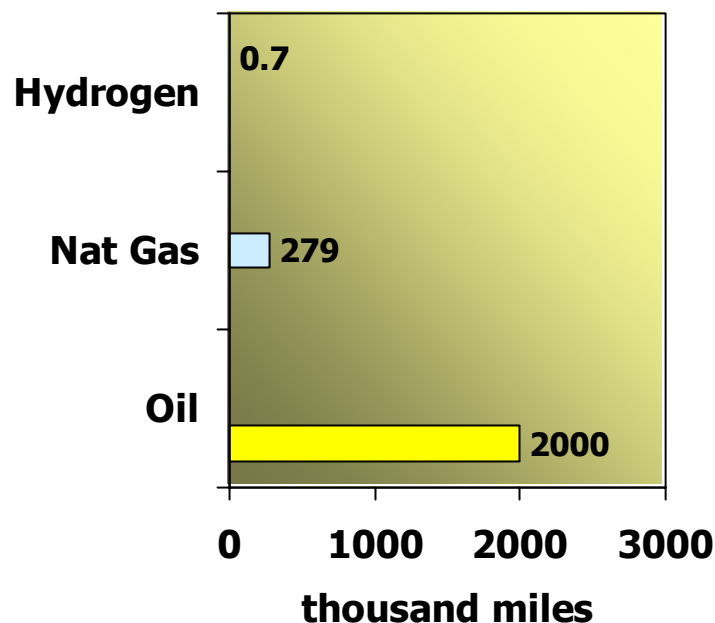
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National Energy Technology Laboratory**



# Hydrogen Delivery Today

- Hydrogen infrastructure exists only for small merchant hydrogen markets in the chemical and refining industries
- Current natural gas infrastructure consists of:
  - Pipelines
  - intermediate product storage
  - import terminals
  - rail, barge, and truck delivery

## U.S. Pipeline Mileage

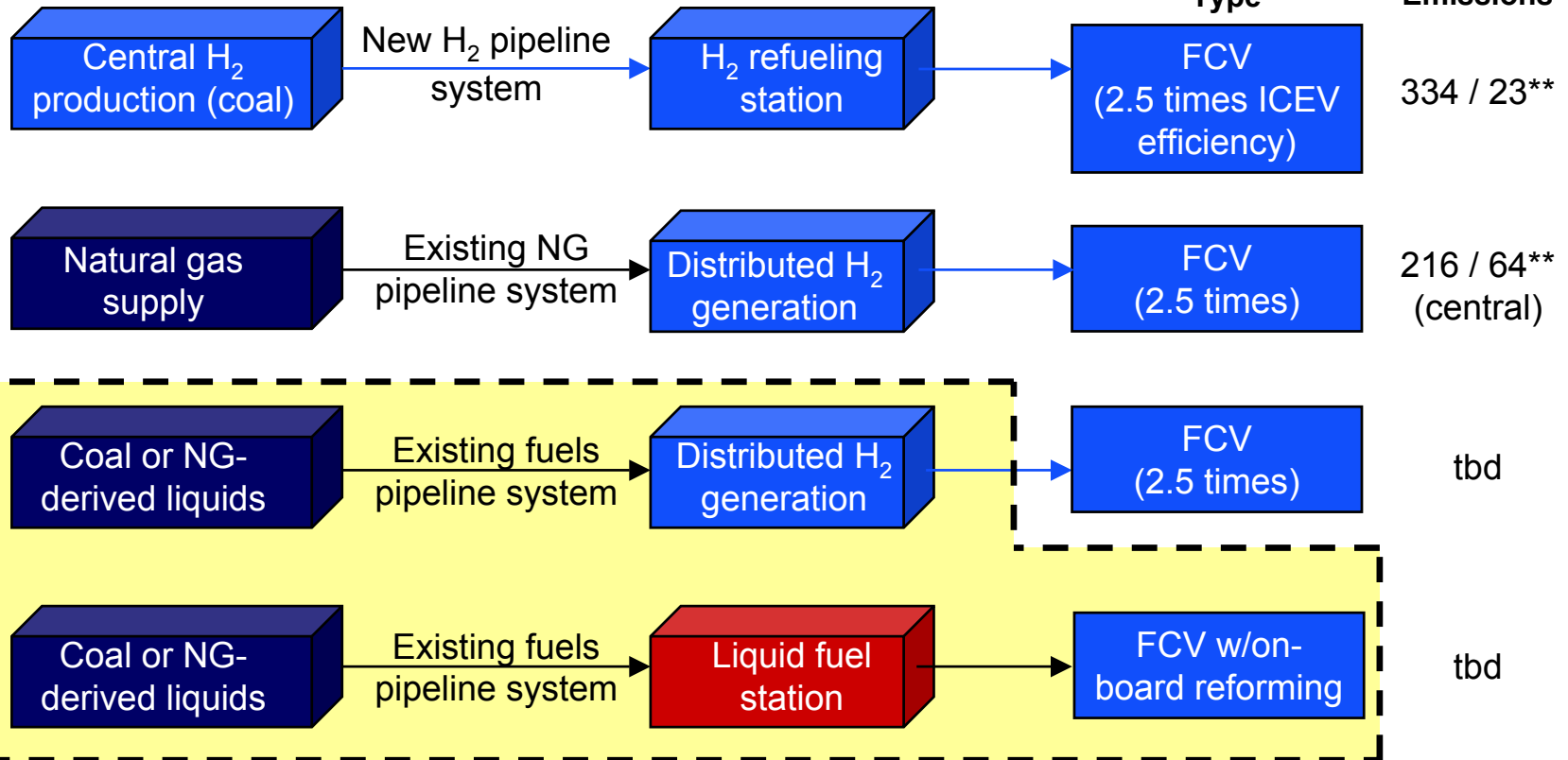


Source: APCI, EIA, NEP

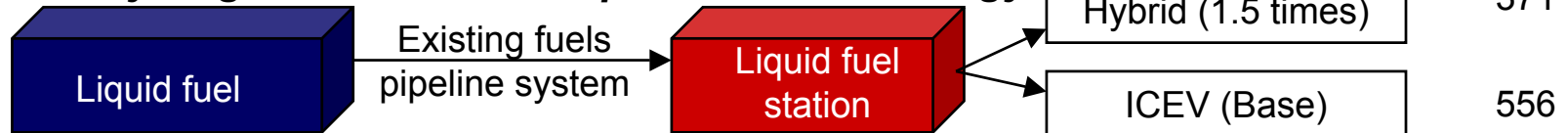


# Comparison of Alternative Delivery Pathways

## Hydrogen FCV Transportation Technology



## Non-Hydrogen non-FCV Transportation Technology



\*CO2 emissions in millions of tons per year for each 100 million vehicles

\*\* Values are for without and with CO2 sequestration.



# Barriers to Hydrogen Delivery

- **Hydrogen infrastructure exists only for small merchant hydrogen markets in the chemical and refining industries**
- **Potential for delivering hydrogen through natural gas infrastructure is likely to be limited: materials; need for separation; safety**
- **Hydrogen has very low energy density by volume**

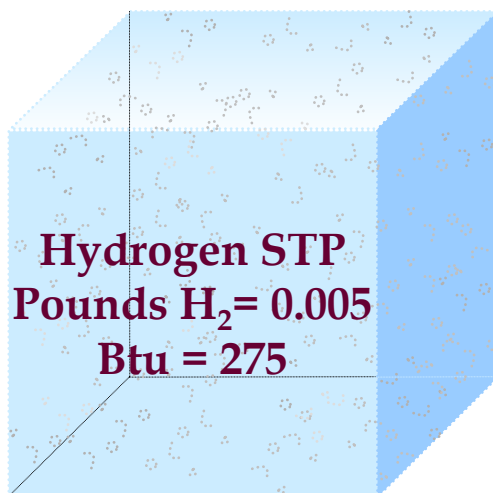


# Hydrogen Storage

**Gasoline**  
#H<sub>2</sub>= 7.3, Btu = 853,000

**Diesel**  
#H<sub>2</sub>= 8.3, Btu = 949,000

**Methanol**  
#H<sub>2</sub>= 6.2, Btu = 430,000



**Compressed H<sub>2</sub> (6000 psi)**  
#H<sub>2</sub>= 2, Btu = 110,000

**Liquid H<sub>2</sub>**  
#H<sub>2</sub>= 4.4, Btu = 229,000

**Metal Hydrides**  
#H<sub>2</sub>= 3.0, Btu = 160,000

**1 Cubic Foot Volume**



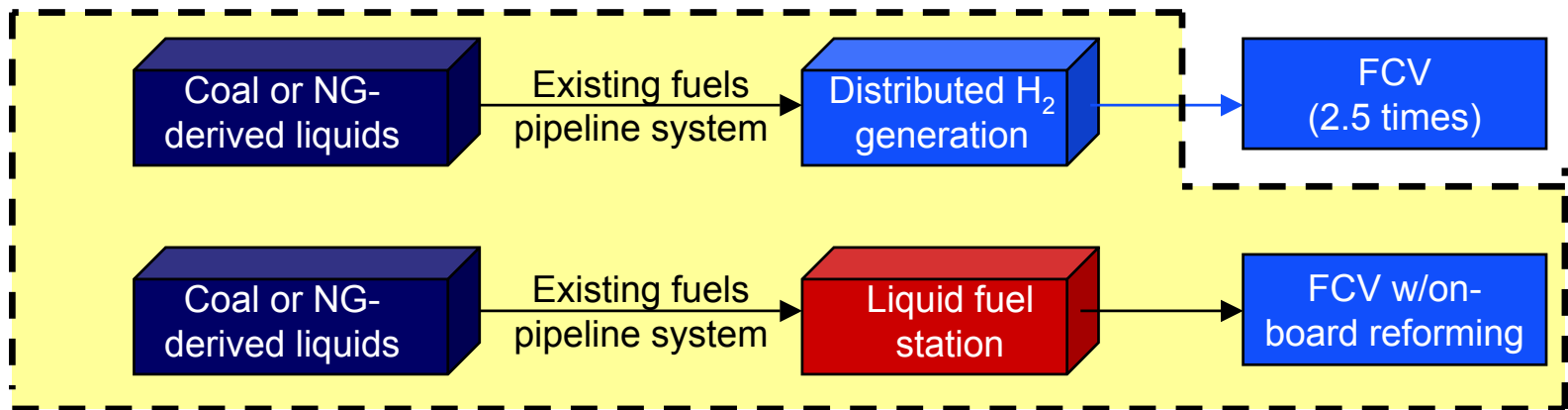
**Air Products & Chemicals, Inc. and  
Eastman Chemical Liquid Phase Methanol  
Demonstration, Kingsport, TN**



# Hydrogen Delivery Via Liquid Hydrocarbons

- **We need to:**
  - Evaluate the potential for coal- (and natural gas-) derived liquids to serve as an interim strategy for delivering hydrogen....and concurrently,
  - Determine the optimum hydrocarbon(s) for delivery and subsequent reforming

## FE Hydrogen Liquid Carrier Systems – Analysis Boundaries



# Distributed Hydrogen Production Technology: Hydrocarbon Feedstock Alternatives

- Service station-sized\* hydrogen production facilities based on reforming natural gas or liquid hydrocarbons  
Service station-sized electrolysis facilities
- On-board reforming of hydrogen-rich, synthesis gas-derived liquid fuel

**Benefit: Early introduction of fuel cell technology**

Georgetown Univ.  
100kw PEM fuel cell-  
powered bus with H<sub>2</sub>  
from methanol



- Service station-sized hydrogen production facility is 800 kg per day (360,000 scfd), which is equivalent to the average U.S. gasoline station sales, when adjusted for FCV efficiency at 2.5 times ICEV efficiency.

# The Future For Coal: Ultra-Clean Energy Plant

**Virtual Simulation**

**Gasification & Combustion**

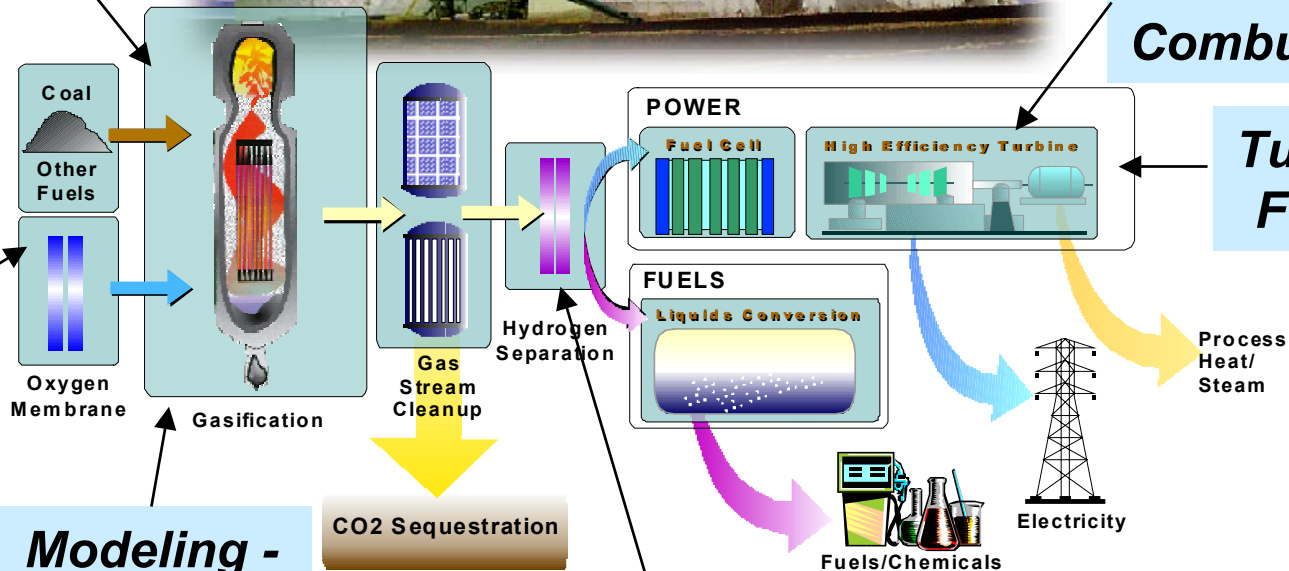
**Systems Integration**

**Advanced Materials**

**Modeling - Combustion**

**Turbines & Fuel Cells**

**Oxygen Membrane**



# Coal to Hydrogen

**Today**

H<sub>2</sub> production  
from Coal @ ~  
\$40 BOE

**2010**

Complete  
development of  
Modules Capable  
of H<sub>2</sub> Production  
from Coal @ \$30

BOE

**2015**

Demonstrate  
Coproduct of H<sub>2</sub>  
from Coal @ \$30 BOE  
when Integrated with  
Advanced Coal Power  
Systems

Separation

Water-Gas Shift  
(WGS)

Storage

**Reforming**

**FY03**

Determine Feasibility of  
One-Step Reforming Process

**FY08**

Complete Fuel Cell Tests With  
Reformed Coal-Derived Liquids

**FY04**

Complete Computational Model  
For Reforming Coal-Derived Liquids

**FY06**

Complete Chemistry for Producing  
Optimum Coal-Derived Liquid(s)